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EEDP-06-18   Documentation of the SETTLE Module for ADDAMS: Design of Confined Disposal Facilities for Solids Retention and Initial Storage (December 1992)

EEDP-06-19   Documentation of the RUNQUAL Module for ADDAMS: Comparison of Predicted Runoff Water Quality with Standards (January 1995)

Environmental Effects of Dredging Technical Notes

Documentation of the SETTLE Module for ADDAMS: Design of Confined Disposal Facilities for Solids Retention and Initial Storage

Purpose

This technical note documents the SETTLE computer program which facilitates the design of a confined disposal facility (CDF) to retain solids, provide initial storage, and meet effluent discharge limitations for suspended solids during a dredged material disposal operation. Detailed information can be found in Engineer Manual 1110-2-5027, "Confined Dredged Material Disposal" (Office, Chief of Engineers (OCE), U.S. Army 1987). Thackston, Palermo, and Schroeder (1988) describes further refinements to these procedures which are used in this module. SETTLE is a part of the Automated Dredging and Disposal Alternatives Management System (ADDAMS).

Background

Confined disposal facilities (CDFs) must be designed to retain and store sediment dredged from navigation channels, estuaries, lakes, and other waterways. Conventional dredging processes add large volumes of water and result in a fluid slurry of solids being discharged into the CDF. Hydraulic dredging operations add this water to facilitate pipeline transport; hydraulically pumped dredged material slurries typically contain sediment concentrations between 50 and 200 g/L depending upon sediment and dredge characteristics. Mechanical dredging operations entrap water during dredging and tend to have higher solids concentrations, usually in the range of 200 to 500 g/L. The disposal of dredged material from either dredge type requires that the CDF provide sufficient hydraulic retention time for removal of suspended solids to meet local, state, and Federal effluent water quality standards.

Water quality certification must be obtained from the state in which the CDF discharge occurs in accordance with Section 401 of the Clean Water Act (U.S. Environmental Protection Agency (EPA) 1980). The certification may specify water quality standards which the effluent from the CDF must meet. State water quality certification usually includes specific concentration limits for water quality constituents of concern and should specify geometric limits for a mixing zone outside of which these concentrations limits may not be exceeded. *Environmental Effects of Dredging Technical Notes* EEDP-04-5 (MacIntyre 1987) describes methods for estimating dilution and mixing zone size for discharges into riverine and estuarine environments. Applying these dilution factors to the state water quality certification limits yields maximum allowable concentration levels in the CDF effluent. Engineer Manual 1110-2-5027 (OCE 1987) provides guidance for designing a CDF for the removal and storage of solids; the SETTLE module described in this technical note implements these procedures along with some refinements of these procedures described by Thackston, Palermo, and Schroeder (1988). *Environmental Effects of Dredging Technical Notes* EEDP-04-1 through EEDP-04-4 (Palermo 1985) present techniques for predicting other constituent concentrations in the CDF effluent. Additional treatment beyond primary clarification within the CDF may be required to meet the effluent standards for some constituents.

Additional Information

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Computational Procedures

Design for Initial Storage

A CDF designed for a single dredging project must be capable of storing the dredged material for a particular disposal activity at its largest volume. This occurs just as disposal ends and is commonly referred to as the initial storage volume. The initial storage volume for the dredged material depends upon many aspects of the dredging project, including sediment characteristics (primarily the fraction of fines versus the fraction of sands), settling characteristics of the material, volume of sediment to be dredged, and disposal rate. The required CDF volume, however, is significantly larger than just the initial volume of sediment to be dredged, particularly for hydraulic dredging transport or disposal projects. The CDF must also include additional depth for ponding to allow sedimentation during the final, and most critical, stage of dredging and dike freeboard above the highest anticipated water surface.

SETTLE determines the average concentration of settled solids within the CDF at the end of disposal, referred to as the design concentration, using the compression settling test data. The design concentration is used to calculate the initial storage requirements for the fine-grained (smaller than No. 200 sieve) fraction of the dredged material. Coarse-grained (larger than No. 200 sieve) material behaves independently and much differently. Thus, the storage volume required for the coarse-grained material is determined based upon the input data and then added to the volume of fine-grained material to yield the minimum initial storage required. The volume is not an estimate of the long-term needs for multiple-disposal activities; it is the volume required for the single disposal project under consideration.

Because of siting, construction, and permitting complications, CDFs are frequently sized to receive multiple disposals. The number and frequency of disposals depend upon the location and dredging projects being served. Under these circumstances, initial storage volume will likely become a constraint only as the CDF ends its service life. Estimates for long-term storage capacity can be made using the consolidation and dessication (PCDDF) module of AD-DAMS (Poindexter-Rollings and Stark 1989).

Initial storage volume can be the controlling design factor regardless of the settling behavior exhibited by the material. In the unusual case that the material exhibits compression settling at a concentration at or below the expected inflow concentration, the design for initial storage might well be the only design consideration required.

Design for Clarification

Sediments containing saline pore water (> 3 ppt salt concentration) frequently settle as a tightly formed soil matrix restricted by the upward flow of water through the matrix. The result is a clarified supernatant above a well defined soil-water interface which continuously settles downward at a slow rate. This is commonly referred to as zone settling. Besides occurring in salt-water sediments, zone settling may occur in freshwater sediments if solids concentrations are high enough or if the particle surface characteristics are flocculent enough.

If the dredged material exhibits zone settling behavior at the expected inflow concentration, the zone settling test results are used to calculate the required ponded surface area in the CDF for effective zone settling (clarification). This surface area is the minimum area required to remove suspended solids from the surface layers at a rate sufficient to form and maintain a clarified supernatant that can be discharged.

Flocculent settling occurs in the supernatant water above the interface and controls the quality of the supernatant. Suspended solids concentration in the clarified supernatant varies widely between sediments but is generally on the order of 50 to 500 mg/L. Additional calculations using flocculent settling data for the solids remaining in the ponded supernatant water are required to

design the CDF for a specific effluent quality standard for suspended solids. These calculations are identical to those described below.

Design for Effluent Quality

The concentration of effluent suspended solids depends on the flocculent settling characteristics of the sediment, the depth from which fluid is withdrawn at the weir, and hydraulic retention time within the CDF. Because of the low viscosity of the supernatant water and the high flow rates commonly found in CDFs, the withdrawal depth is essentially equivalent to the ponded water depth. SETTLE uses the average ponded depth to estimate the residence time and compute the average solids concentration in the discharge. A minimum average ponded depth of 2 ft is usually recommended for the design; greater depths of ponding reduce the surface area required for adequate solids removal. For most cases, constant ponded depth can be maintained by raising the weir crest and, hence, water surface elevation as settled material accumulates in the CDF.

CDFs constructed in a rectangular shape with sides as near the same length as possible minimize the dike length required for a given surface area or storage volume. This typical shape combined with point source inflows result in an actual hydraulic retention time considerably less than the theoretical retention time. Thus, calculating the effluent suspended solids concentration requires correcting the theoretical retention time for hydraulic inefficiencies. Actual mean hydraulic retention time and hydraulic efficiency for a given flow rate, design area, and ponding conditions and the theoretical residence time can be estimated using the DYECON module (Hayes and Schroeder 1992).

Calculating Weir Length

The fact that withdrawal depth is essentially the ponded water depth at the weir does not minimize the importance of determining the necessary weir length. The weir must be long enough that the overflow rate does not attempt to draw water from depths greater than the depth of the free water surface pond. The settled solids layer is loosely compacted and scouring begins at very low velocities. High overflow rates may cause enough scouring of settled solids to violate effluent water quality standards. SETTLE calculates the weir length necessary to avoid this entrainment of solids for slurries that underwent either zone or flocculent settling.

SETTLE Application of ADDAMS

Introduction

A properly designed CDF removes solids from the dredged material slurry sufficiently to meet state water quality certification and safely provides temporary or permanent storage for the retained solids. A schematic of a CDF is shown in Figure 1. The quality of water discharged from a CDF is a

MOUNDED COARSE-GRAINED
DREDGED MATERIAL

DEAD ZONE

WEIR

INFLUENT

AREA FOR SEDIMENTATION

EFFLUENT

DEAD ZONE

PLAN

INFLUENT

PONDING DEPTH

FREEBOARD

AREA FOR SEDIMENTATION

WEIR

COARSE-GRAINED
DREDGED MATERIAL

AREA FOR FINE-GRAINED
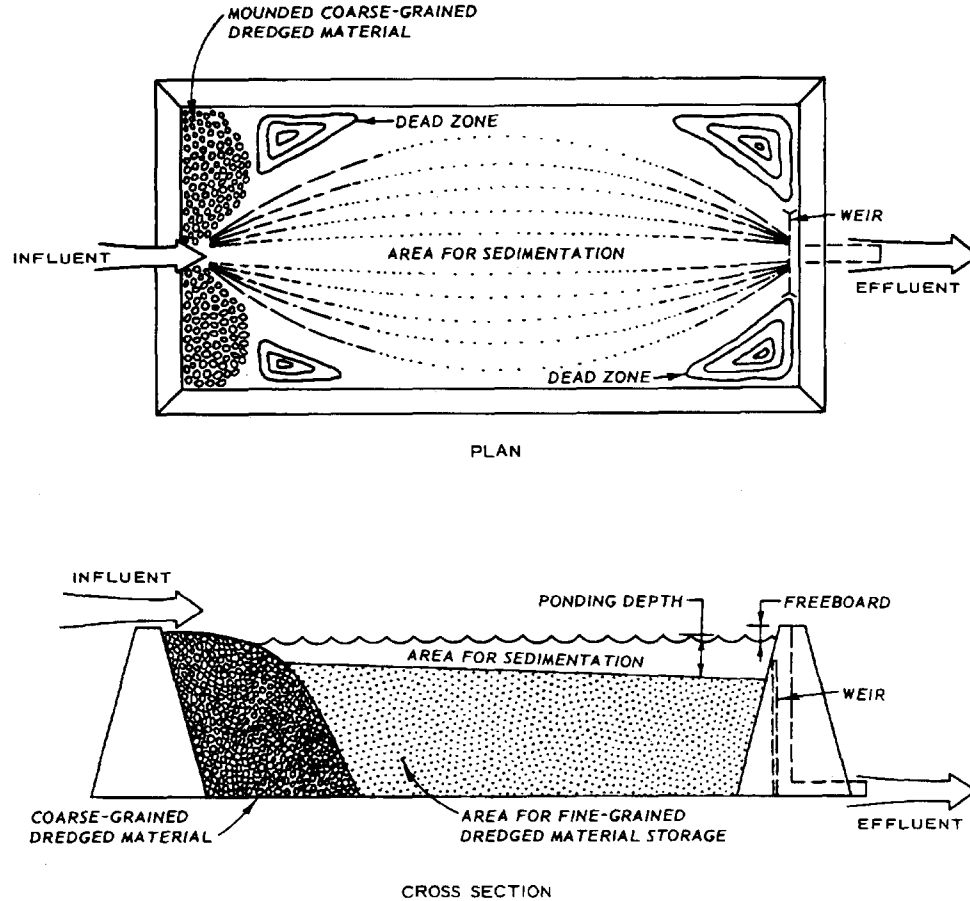DREDGED MATERIAL STORAGE

EFFLUENT

CROSS SECTION

Figure 1. Schematic of a confined disposal facility

significant environmental concern associated with dredging, especially in areas where the dredged material may contain contaminants of concern. Thus, it is important to size and operate the CDF in such a manner that the best practicable solids and contaminant removal occurs. This is accomplished by designing the CDF for solids removal during the most critical stage of the disposal operation; the most critical stage usually occurs during the final days of disposal when the ponded volume is the least. Designing for this critical stage ensures adequate removal during the entire dredging operation.

CDF design, however, is not simply determining the surface area required for solids removal and initial volume required to store the freshly deposited dredged material. Surface area, free water ponded depth, hydraulic efficiency, weir length, inflow rate, and inflow concentration all affect solids removal efficiency in a CDF. Large surface area and storage volume requirements combined with land acquisition difficulties usually make overconstruction economically prohibitive. Thus, the design of a CDF requires careful evaluation of these design variables in conjunction with design constraints. For example, land constraints can substantially restrict the area available for construction of the CDF. The CDF design must then focus on controllable design aspects

which affect effluent water quality such as ponded water depth, inflow rate, and weir length. If the allowable range of modification for these parameters cannot meet state water quality certification requirements, additional treatment may be required before discharging the CDF effluent into the receiving body.

Capabilities

SETTLE is a computer program and module of the ADDAMS. The general goal of ADDAMS, an interactive computer-based design and analysis system for dredged material management, is to provide state-of-the-art computer-based tools that will increase the accuracy, reliability, and cost-effectiveness of dredged material management activities in a timely manner. *Environmental Effects of Dredging Technical Notes* EEDP-06-12 (Schroeder and Palermo 1990) describes ADDAMS in more detail.

SETTLE implements CDF design procedures described in Engineer Manual 1110-2-5027 (OCE 1987) and refinements described by Thackston, Palermo, and Schroeder (1988). It performs CDF design calculations based on data from laboratory settling tests, information on the dredging project, anticipated dredged volumes, dredged material characteristics, expected hydraulic efficiency of the CDF, and desired effluent quality. SETTLE can consider constraints on the CDF design such as dike height and surface area limitations in the design calculations and provides the capability to consider all CDF design alternatives. A user should gain a working knowledge of EM 1110-2-5027 prior to running SETTLE.

The SETTLE module of ADDAMS has the following specific capabilities:

- Analyze and reduce laboratory settling test data required for CDF design.
- Size a CDF for solids retention and initial storage of dredged material.
- Compute the weir length required to prevent resuspension and excessive discharge of suspended solids.

Availability

SETTLE, as well as other modules of ADDAMS, is available through the Information Technology Laboratory of the U.S. Army Engineer Waterways Experiment Station. See Appendix A for an order form.

Using SETTLE

SETTLE may be started from the ADDAMS executive shell by selecting the SETTLE program (option 1) or started separately by typing SETTLE at the DOS prompt. The method of starting SETTLE should be chosen based upon familiarity with the DOS operating system, available RAM, system configuration, and the existence of other ADDAMs modules. It is primarily a matter of personal preference, however, since SETTLE operates the same regardless of how it is initiated. Users of the ADDAMS executive shell may receive a DOS error

message (Table 1) indicating insufficient RAM available to run SETTLE (or other ADDAMS modules). This happens because too much RAM is being used for other applications by your computer while you are trying to execute the SETTLE executable module. If this occurs, the user should increase the available RAM by modifying the CONFIG.SYS and the AUTOEXEC.BAT files. The DOS manual explains how to modify these files to increase available RAM. Common depletion of available RAM is caused by DOS requirements, engagement of a network, mouse, print buffer, menu or terminate and stay resident (TSR) programs.

Table 1. DOS Error Messages Indicating Insufficient Memory to Execute SETTLE

DOS version	Error Message
3.x	Program too big to fit in memory
4.x	Program too big to fit in memory
5.x	Cannot execute c:\addams\settle.exe

General Operation

SETTLE operates in a user-friendly, menu-driven environment and facilitates data entry and editing by using a full-screen editor approach. A central menu, called the *SETTLE Activity Selection Menu*, allows the user to select the desired operation such as enter/edit settling test data or dredging project data, perform file management operations, perform design calculations based on user-entered settling test data or settling data for typical or conservative small projects, and set the hardware configuration for the SETTLE graphics. All menu selections are numbered and may be selected by pressing the number of the desired option. The user may also choose to cycle through the menu options using the up arrow ($\uparrow$) or down arrow ($\downarrow$) key and then select the highlighted option by pressing the ENTER key.

Each option, except the enter/edit settling data option, provides the user with a full screen editor for data entry and editing. Most editing screens describe several required data items with the current value for the data item displayed. Editing focuses on the highlighted data item or question. Descriptions of the data item and options are usually located to the left of the cell; units are displayed to the right of the cell. The user may enter a new value in the cell or modify the value in the cell. Moving to another data item on the current screen requires pressing either the ENTER key, the TAB key, or one of the vertical arrow keys. Page Down and Page Up keys display the next and previous screens, respectively. The enter/edit settling data option provides a similar menu to the *SETTLE Activity Selection Menu* containing menu options for entering or editing specific settling test data.

SETTLE presents the results of design computations on descriptive screens similar to the full-screen data editor. Results are often displayed in tabular

format and include relevant assumptions, equations used, and controlling factors so the user can appropriately assess the design results. SETTLE will also print the results to ASCII output files or directly to the printer.

Getting Started

The user should establish the proper hardware configuration prior to any other use of SETTLE. Hardware configuration can be established or modified by selecting menu item 8, perform hardware configuration for graphics. SETTLE uses the stored configuration to display and print graphics and other output. Modifications to the hardware configuration are not required after the initial setup unless the available hardware changes or the configuration data file is lost.

After the initial hardware configuration, later uses of SETTLE should begin by selecting (or making "active") the desired data file. SETTLE initially recalls the data file from the previous session and makes it the "active" data file. A different data file or new data file can be activated by using the ADDAMS File Manager. The File Manager is initiated by selecting menu item 7, perform data file selection and operation. The ADDAMS File Manager and its operation are discussed in detail by Schroeder and Palermo (1990). When the File Manager returns control to SETTLE, the active data file, if it exists, is read and values assigned to appropriate variables. Note that SETTLE does not offer an option to change the name of the active data file after it has been read. Thus to modify an existing data file and retain the original file, the user must change the active file name to the desired name for the modified file before saving the data. This operation is performed using the ADDAMS File Manager, but must be done before modifications are saved to prevent loss of the original data.

On-line Help

On-line comprehensive help messages are available to SETTLE users by pressing F1 or Alt-F1. Pressing the F1 key provides general assistance on the current menu and information regarding choices the user needs to make. Detailed assistance for the currently highlighted data item is available on-line by simultaneously pressing the Alt and F1 keys. These context-sensitive messages provide detailed information about the user's options at the current position and/or describe data to be entered or edited at the current cursor position. Help messages may also provide default values or typical ranges.

Hardware Requirements

SETTLE requires a MS-DOS based personal computer with at least 640 kilobytes of RAM, a hard disk with 2 megabytes of free space, and a CGA, EGA, or higher resolution color video card and compatible monitor.

CDF Design Using SETTLE

Designing a CDF consists of sizing for initial storage of the slurried dredged material and adequate clarification to meet effluent quality standards through solids removal. While sizing for initial storage is relatively straightforward, solids removal depends on a combination of surface area, ponded water depth, hydraulic efficiency, average inflow rate, and weir length. The final CDF design must satisfy both storage and effluent quality criteria within the physical constraints placed upon the site. Design calculations in SETTLE are based upon the procedures described in EM 1110-2-5027 (OCE 1987) and require laboratory settling test data and dredging project data which reflect the anticipated use of the CDF. A series of SETTLE runs should be used to evaluate an array of design alternatives and select the most appropriate design balancing requirements for storage and effluent quality.

Data Requirements

Various settling processes begin immediately once dredged material is discharged into the CDF. A properly designed CDF facilitates these settling processes to enhance solids removal, compaction, and fractional retention of solids. Dredged material slurries exhibit either flocculent or zone settling, depending on the slurry concentration, particle type, and salinity of the carrier water. Slurries with salinity greater than 3 ppt usually exhibit zone settling because the dissolved ions act as a coagulant. Freshwater slurries typically exhibit flocculent settling but may exhibit zone settling if solids concentrations are high enough or if the particle surface characteristics exhibit low stability forces.

Regardless of whether the upper layers of the settling material in the CDF exhibit flocculent or zone settling, the bottom layers of settled material will exhibit compression settling or thickening. As settled solids accumulate, the concentration of settled solids in the bottom layers increases. Settled solids begin to rest on and be supported by the bottom of the disposal area. Successive layers of settled solids then rest on each other. The point at which the bottom begins to provide some physical support, compression settling begins. The change from flocculent or zone settling to compression settling occurs at a concentration of approximately 200 to 300 g/L for most dredged material slurries.

Sedimentation characteristics can vary widely between sediments. Thus, laboratory test data reflecting the settling properties of the dredged material planned for disposal must be available to appropriately design the CDF. Data requirements for a complete design analysis include laboratory results from a flocculent settling test, a 15-day compression settling test, a zone settling test, when zone settling occurs, disposal area information, dredge information, and physical and engineering properties of the dredged material; specific requirements for each data type are described below. SETTLE runs can be made using data from a partial set of settling tests; however, this provides only design information based on the results of those tests.

Entering/Editing Settling Test Data

Option 1 of the *SETTLE Activity Selection Menu*, enter/edit settling data menu, activates the *Settling Data Selection Menu* which allows the user to enter data for any of the three specific types of settling tests. Selecting a settling test type from this menu initiates a sequence of full screen data entry menus tailored specifically for that settling test. These screens describe the data being requested, provide graphics where applicable, and display results of the reduced settling test data. If settling data has previously been entered for the active file, the user may edit the existing data on these same screens. SETTLE automatically reduces the data and recomputes all coefficients prior to the results or graphics screens. Once the series of menus for the selected test are completed, SETTLE returns to the *Settling Data Selection Menu*. Pressing the Esc key at that point returns control to the *SETTLE Activity Selection Menu*.

Compression Settling Data. Data entry for the compression settling option consists of two data input screens plus one results screen and an optional graphical display of the test results. Table 2 lists the necessary input parameters from the compression settling tests and their corresponding units. From the interface height and initial solids concentration data, SETTLE computes the settled solids concentration at each time the interface height was measured. The settled solids concentration versus time data are fitted (using the least-squares technique) to a power curve of the form:

$$C = aT^b \tag{1}$$

where

C = settled solids concentration, g/L
T = time since disposal, days
a,b = regression coefficients

The results screen shows the computed power function and its coefficient of determination. The user can choose to view a graph of the data and fitted curve, to examine for goodness-of-fit, outliers and typographical errors in data entry. The graph can also be sent to the printer or plotter specified in the hardware configuration file. See Figure 2 for an example plot.

Table 2. Compression Settling Data Requirements and Associated Units

Parameter	Units
Average influent solids concentration	g/L
Initial height of slurry in column	ft
Times when solids interface height was measured	days
Solids interface height at times when interface was measured	ft

SOLIDS CONC - g/l (vertical axis)

1000.00

100.00

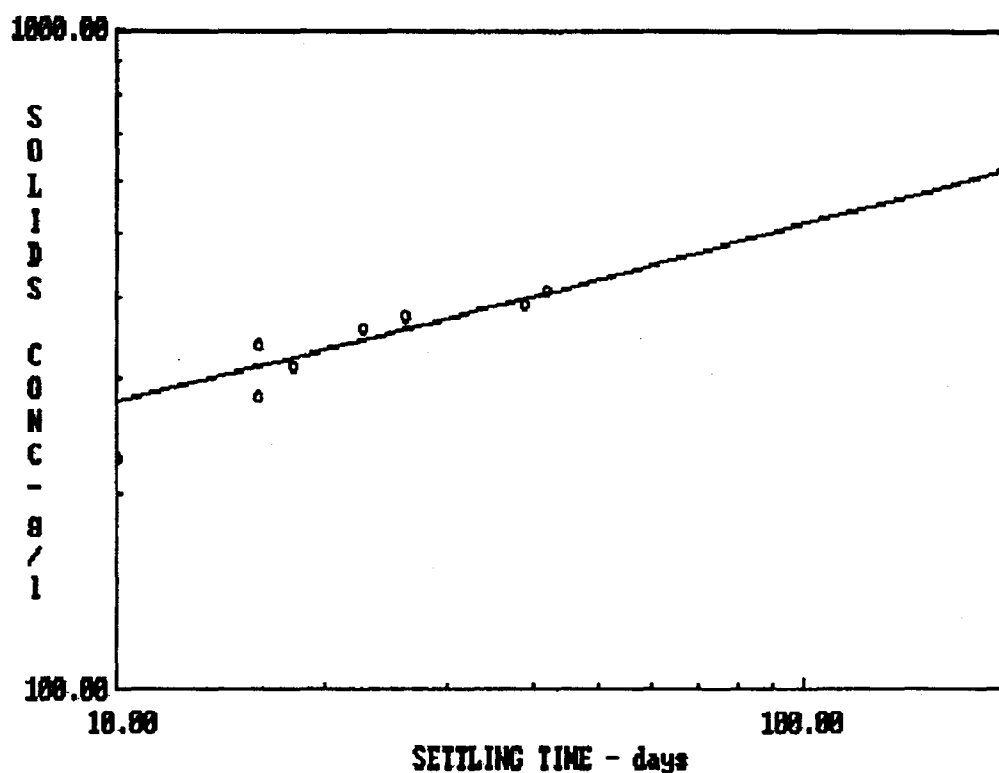10.00 ... 100.00

SETTLING TIME - days

Figure 2. Example plot of compression settling data

Flocculent Settling Data. Flocculent settling data entry consists of three data input screens, three data reduction results screens, and one graph of the flocculent settling data. Table 3 lists the input parameters with their corresponding units. From the raw flocculent settling data which is entered in the first three screens, SETTLE computes the percent of the initial suspended solids concentration remaining in suspension for each sample. It displays the results on screen in a matrix of sampling times (rows) and port heights (columns). Power curves of the suspended solids concentration as a function of depth from the surface are fitted (using the least-squares technique) for each sampling time. The curves are of the form

$$C_T = a'D^{b'} - C'_T \qquad (2)$$

where

C_T = suspended solids concentration, mg/L

D = depth from water surface, ft

C'_T = suspended solids concentration at the surface, mg/L

T = time since disposal, hr

a', b' = regression coefficients

Table 3. Flocculent Settling Data Requirements and Associated Units

Parameter	Units
Heights of the sampling ports	ft
Sampling times	hr
Height of the water surface at the sampling times	ft
Suspended solids concentration of the supernatant samples	g/L

SETTLE displays the regression equations and their coefficients for each time. Regression coefficients are not displayed since each curve results from only a small number of data points (usually 2 to 4) and the values would have little significance. A number of constraints are placed upon the regression results to ensure reasonable curves when using only a small number of data points. An option to allow the user to modify these coefficients to better fit the data may be added at a later time. A graphical display of the flocculent settling data and the fitted curves is available so the user can visualize the regression results. An example plot is shown in Figure 3.
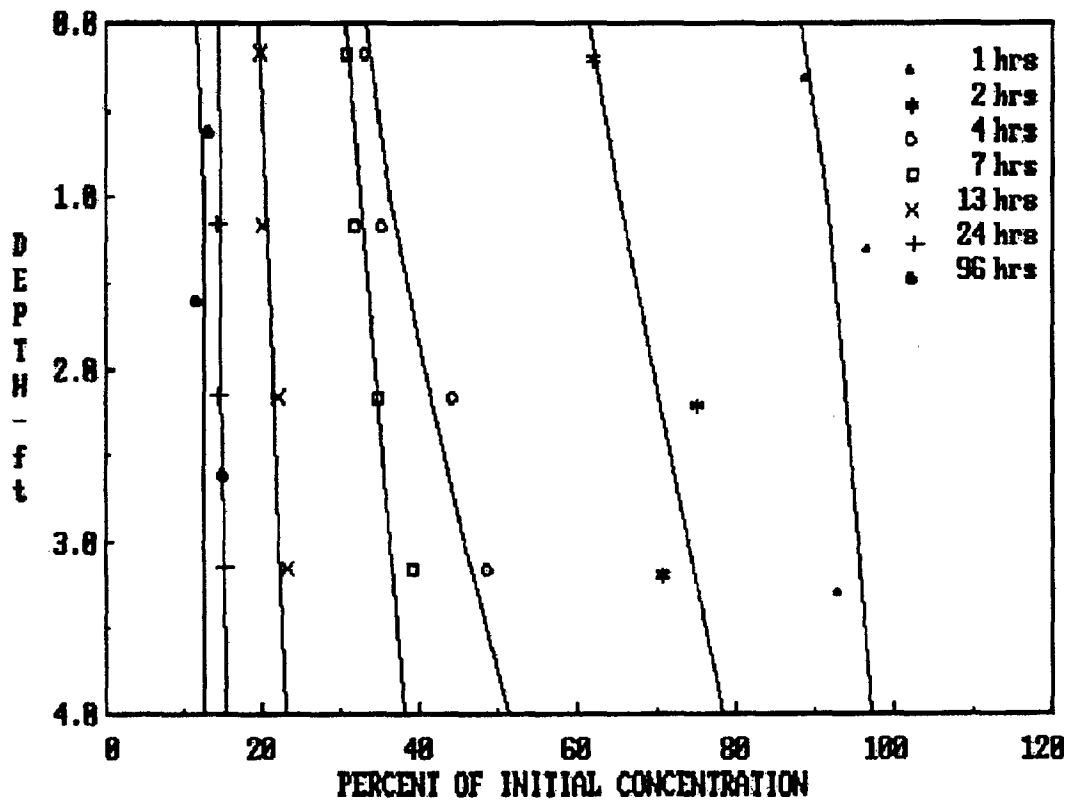

Figure 3. Example plot of flocculent settling data

SETTLE uses the regression equations to compute the suspended solids removal percentages as a function of the sampling times for user-specified withdrawal depths. Solids removal increases with time and decreases with increasing depths of withdrawal. The computed values are displayed for the user to evaluate.

Zone Settling Data. Zone settling data entry consists of only one screen for the interface height versus time data; Table 4 describes the input data along with their corresponding units. A second screen displays the zone settling velocity computed as the maximum negative slope separating two points in time at least 2 hr apart. The screen also displays its point of tangency. Unfortunately this is not a perfect criteria for determining the zone settling velocity. Thus, an option for viewing the data and zone settling velocity line is also provided and the program permits the user to enter his own zone settling velocity. The graph displays the user-defined zone settling velocity and point of tangency. The user should try several values of zone settling velocity, viewing each on the graph provided, to determine the zone settling velocity which should be used. The user-defined zone settling velocity is used in all design calculations. An example plot of the zone settling data is shown in Figure 4.

Table 4. Zone Settling Data Requirements and Associated Units

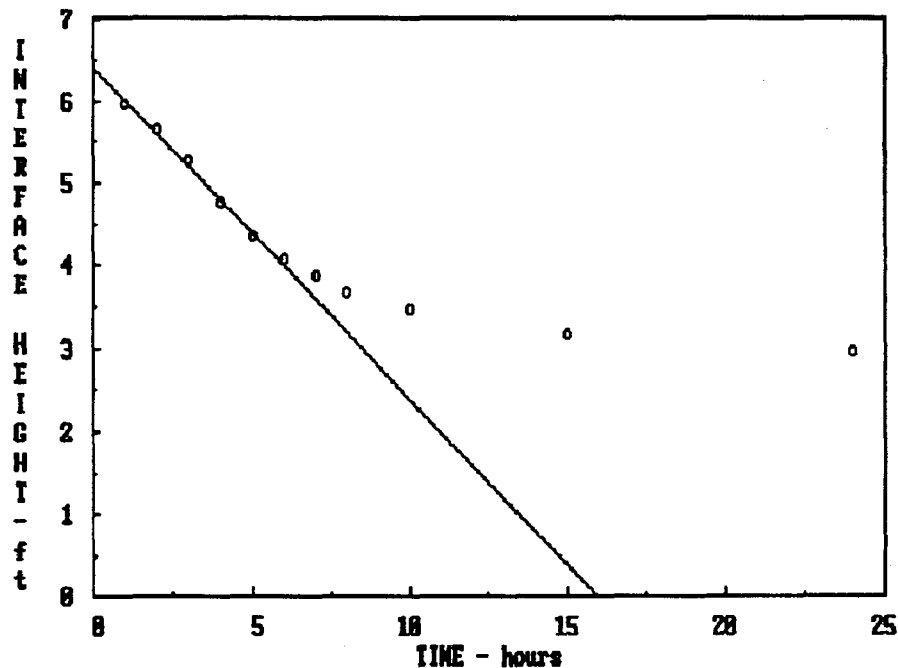| Parameter	Units
Times when solids interface height was measured	hr
Solids interface height at times when interface was measured	ft

Figure 4. Example plot of zone settling data

Entering/Editing Project Data

Selecting option 2, enter/edit project data, from the *SETTLE Activity Selection Menu* initiates the entry and editing process for data describing the dredging project. Table 5 lists the required project data and appropriate units. Close inspection of the list in Table 5 indicates some apparent overspecification. For example, it appears that the inflow rate, pipe velocity, and pipe diameter are required input data; actually, the user only needs to input any two of these parameters and SETTLE computes the third. Similarly, the input for several project data parameters can be expressed in alternative ways; in situ sediment solids concentration can be expressed in terms of water content or void ratio and specific gravity. SETTLE allows the user to enter the data either way and then calculates the value for the other. Some of the input parameters may also be the focus of design calculations. Although they are not required, entering them does not affect the design calculations. For example, if you wish to determine the minimum area and volume required for storage given the dike height, depth of ponding, and freeboard, the interior area for storage need not be specified because it will be the result of the analysis as opposed to a variable used in the analysis.

Table 5. Project Data Requirements and Associated Units

Parameter	Units
In situ sediment volume to be dredged	cu yd
Quantity of coarse-grained material in sediment in percent weight	percent
Average specific gravity of sediment	unitless
Average in situ void ratio of sediment	unitless
Average in situ water content of sediment	percent
Influent suspended solids concentration	g/L
Production rate of dredge (in situ sediment)	cu yd/hr
Influent flow rate	cfs
Influent dredge pipe diameter	feet
Influent pipeline flow velocity	ft/sec
Dredging or disposal duration	days
Disposal time per day	hours
Percent of disposal time spent as down time	percent
Dike crest height	feet
Freeboard depth	feet
Depth of ponded water	feet
Total interior surface area of CDF for storage	acres
Percent of storage area ponded	percent
Hydraulic efficiency	percent
Effluent suspended solids limit	mg/L

The project data are entered through four data input screens. The first two screens request information about the sediment to be dredged — dredging volume, percent fines, specific gravity, and settled sands concentration. The third screen asks for dredge production data such as pipe diameter, inflow concentration, inflow rate, and pipe velocity. Disposal area configuration constraints are entered in the final screen. These constraints include maximum dike height, minimum depth of ponded water, maximum total and ponded surface area considering effects of sloped dikes, minimum dike freeboard, minimum hydraulic efficiency, and maximum effluent solids concentration.

Program Execution using Laboratory Settling Data

Once the settling test and dredging project data have been entered, SETTLE is ready to determine the desired parameters by performing design calculations for the CDF. Design calculations using laboratory settling data are initiated by selecting option 3, execute using laboratory settling data, from the *SETTLE Activity Selection Menu*. Selecting this option provides the user with a screen containing available design options (Table 6) for initial storage, clarification, and effluent quality. The user must select the design parameter (for example, surface area, ponded depth, and dike height) to be calculated for each criteria. The design parameters for each criteria are fully independent; the user may select the same or different design parameters for each criteria.

Table 6. Design Options Available for SETTLE Runs

Compression Settling for Initial Storage	Zone Settling for Clarification	Flocculent Settling for Effluent Quality
None	None	None
Minimum area and storage volume	Minimum ponded area and interior area for clarification	Minimum area, ponded area and volume, and mean residence time
Min. avg. depth of dike height, storage volume and depth	Maximum influent flow rate for clarification	Min. ponded depth and volume, and mean residence time
Max. flow rate, max. production rate and min. disposal period		Max. flow rate and min. residence time
Max. volume of in situ material		Effluent suspended solids concentration

One of four design parameters can be calculated based on the compression settling data; two based on the zone settling data; and three based on the flocculent settling data. Compression settling data may be used to compute either the initial storage volume required given the disposal duration, the minimum dike height required to provide adequate storage volume given the surface area of the disposal facility and the disposal duration, the maximum influent flow rate that permits compression settling to reduce the storage requirements

to the available volume of the disposal facility, or the minimum storage area required to provide adequate storage volume given the dike height and the disposal duration.

Zone settling data may be used to compute either the minimum area required for effective zone settling given the influent flow rate or the maximum influent flow rate permitted for effective zone settling given the ponded surface area of the disposal facility.

Flocculent settling data may be used to compute either the effluent suspended solids concentration given the ponded water depth, ponded area and influent flow rate; the minimum surface area required to achieve the desired effluent suspended solids concentration given the depth of ponding and influent flow rate; the maximum influent flow rate permitted to achieve the desired effluent suspended solids concentration given the ponded depth and ponded area; or the minimum depth of ponding to achieve the desired effluent suspended solids concentration given the ponded area and the maximum influent flow rate. The actual minimum ponded depth must be great enough to prevent scouring and resuspension.

Once the user has decided upon the design parameters to be computed and presses the Page Down key, SETTLE performs the design calculations. If data are missing for any of the three analyses requested, the program will list the types of data missing and then perform the calculation for those analyses where all data requirements had been satisfied. The following screen summarizes the results by settling type. If flocculent settling results are available, the user may view a graph of effluent concentration versus retention time for up to three withdrawal depths specified by the user. Additional screens follow which present the equations upon which the design for compression settling, zone settling, and flocculent settling are based. These screens include variable definitions and limiting assumptions for each equation. SETTLE can also print the results to a connected printer.

Using Typical and Conservative Small Project Data

Some small dredging projects do not warrant the expense and delay involved in conducting the laboratory settling tests. SETTLE provides two options to performing design calculations for these small projects. Schaefer and Schroeder (1988) compiled results from a number of settling tests and developed representative settling test data sets for use in small projects. One data set was developed corresponding to anticipated or typical settling characteristics. A second data set corresponding to conservative settling characteristics was also developed. SETTLE provides these sets of settling data for small projects under option 4, Execute using typical small project data, and option 5, execute using conservative small project data, of the *SETTLE Activity Selection Menu*.

SETTLE presents design results for the small project data in the same manner as described for the laboratory settling test data, substituting default

settling characteristics for the laboratory settling test results. These options should only be as a last resort for small projects or planning.

Calculating Weir Length

SETTLE calculates the weir length necessary to avoid entrainment of solids for either zone or flocculent settling under option 6, perform weir length design, of the *SETTLE Activity Selection Menu.* Selecting this option displays a screen allowing the user to select weir length design for either flocculent or zone settling and showing the current withdrawal depth and design flow rate. The user may enter or edit the desired withdrawal depth or design flow rate and SETTLE will recalculate the weir length.

File Operations and Hardware Setup

File operations (Option 7) and hardware configuration for graphics (Option 8) are described earlier in the section entitled "Getting Started." Graphics are an integral part of the design process using SETTLE. As a minimum, the user should specify the proper type of video display adapter and monitor to display graphics. Similarly, users should become familar enough with file operations to save their data in a file or retrieve/read their data from a file previously saved.

Applying SETTLE Results

SETTLE calculates design parameters based on laboratory settling test data and dredging project data. It provides CDF sizing calculations based on the three types of settling which are likely to occur in a CDF--compression settling, zone settling, and flocculent settling. The SETTLE user must understand the differences in these settling characteristics and be capable of determining which controls the design for the project of interest.

In cases where the effluent quality restrictions include parameters other than suspended solids concentration, the ADDAMS module EFQUAL (Palermo and Schroeder 1991) should be used in conjunction with SETTLE to design the CDF.

Summary

SETTLE is another ADDAMS tool which facilitates proper dredged material management by providing an effective and efficient means of performing CDF design calculations. SETTLE is easy to use and encourages the evaluation of an array of design alternatives. It does not, however, preclude the need for laboratory settling tests on the dredged material to be placed in the CDF. These tests will continue to be required until reliable relationships between sediment characteristics and settling properties can be established.

References

Hayes, D. F., and Schroeder, P. R. 1992 (Dec). "Documentation of the DYECON Module for ADDAMS: Determining the Hydraulic Retention Time in Confined Disposal Facilities," *Environmental Effects of Dredging Technical Notes* EEDP-06-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

MacIntyre, D. F. 1987. "Interim Procedures for Estimating Mixing Zones for Effluent from Dredged Material Disposal Sites (Single-point Discharge)," *Environmental Effects of Dredging Technical Notes* EEDP-04-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Office, Chief of Engineers, U.S. Army. 1987. "Confined Disposal of Dredged Material," Engineer Manual 1110-2-5027, Washington, DC.

Palermo, M. R. 1985. "Interim Guidance for Predicting the Quality of Effluent Discharged from Confined Dredged Material Disposal Areas, Note 1 - General; Note 2 - Test Procedures; Note 3 - Data Analysis; and Note 4 - Application," *Environmental Effects of Dredging Technical Notes* EEDP-04-1 through EEDP-04-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Palermo, M. R., and Schroeder, P. R. 1991. "Documentation of the EFQUAL Module for ADDAMS: Comparison of Predicted Effluent Water Quality with Standards," *Environmental Effects of Dredging Technical Notes* EEDP-06-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Poindexter-Rollings, M. E., and Stark, T. D. 1989. "PCDDF89 - Updated Computer Model to Evaluate Consolidation/Dessication of Soft Soils," *Environmental Effects of Dredging Technical Notes* EEDP-02-10, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Schaefer, T. E., and Schroeder, P. R. 1988. "Confined Disposal Guidance for Small Hydraulic Maintenance Dredging Projects - Design Procedures," *Environmental Effects of Dredging Technical Notes* EEDP-02-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Schroeder, P. R., and Palermo, M. R. 1990. "The Automated Dredging and Disposal Alternatives Management System (ADDAMS)," *Environmental Effects of Dredging Technical Notes* EEDP-06-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Thackston, E. L., Palermo, M. R., and Schroeder, P. R. 1988. "Refinement and Simplification of Column Settling Tests for Design of Dredged Material Containment Areas," *Environmental Effects of Dredging Technical Notes* EEDP-02-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Environmental Protection Agency. 1980 (24 Dec). "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," *Federal Register*, Vol 45, No. 249, pp 85, 336-85, 358.

APPENDIX A: REQUEST FORM FOR ADDAMS

Please send the ADDAMS diskettes to:

Name and Title _____
Mailing Address _____
   and Office Symbol _____

_____
Telephone Number _____
Anticipated uses of ADDAMS _____

_____

Requests for ADDAMS must be sent with *formatted* floppy disks in a self-addressed mailing envelope. When ordering individual modules, also select the Executive Shell. Please circle the applications desired and the number and type of diskettes enclosed

| Requested Modules	Number of diskettes enclosed (all DS)			
	5.25 in. 360 kb	5.25 in 1.2 Mb	3.5 in. 720 kb	3.5 in. 1.44 Mb
ADDAMS (all modules)	13	9	9	8
SETTLE	2	1	1	1
PCDDF	2	1	1	1
DYECON	2	1	1	1
D2M2	1	1	1	1
DUMP	4	2	2	1
EFQUAL	1	1	1	1
WET	1	1	1	1
EXECUTIVE SHELL	1	1	1	1

Signed_____Date_____

MAIL THE COMPLETED REQUEST FORM AND FORMATTED DISKETTES TO:

> US Army Engineer Waterways Experiment Station
> ATTN: CEWES-IM-MI-C (Naylor)
> 3909 Halls Ferry Road
> Vicksburg, MS 39180-6199
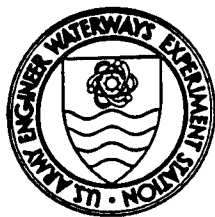
Environmental Effects of Dredging
Technical Notes
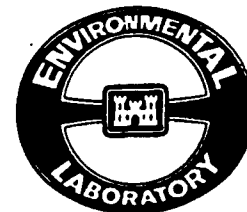
Documentation of the RUNQUAL Module for ADDAMS: Comparison of Predicted Runoff Water Quality with Standards

Purpose

This technical note has a twofold purpose: to describe a technique for comparing the predicted quality of surface runoff from confined dredged material disposal areas with applicable water quality standards and to document a computer program called RUNQUAL, written for that purpose as a part of the Automated Dredging and Disposal Alternatives Management System (ADDAMS).

Background

The U.S. Environmental Protection Agency (EPA) (1980) has published guidelines for implementing the 1977 amendments of section 404 of the Clean Water Act for water quality impacts associated with dredged material disposal. Proposed testing requirements define dredged material according to four categories, with Category 3 consisting of material proposed for confined disposal that has "potential contamination of the receiving water column only." The proposed testing requirements call for evaluation of long-term water column impacts of disposal area surface runoff discharge. In addition, under section 401 of the Clean Water Act, a water quality certification is required from the state in which the surface runoff occurs. The certification can include water quality standards for contaminants of concern and should specify the size of a mixing zone for initial dilution in those cases where receiving water quality standards may be exceeded.

In this context, surface runoff refers to the discharge from the surface of dewatered dredged material in response to a precipitation event. The quality of surface runoff from confined dredged material disposal areas during both the wet anaerobic and the dry oxidized stages is a major environmental concern

associated with such disposal. Comparison of water quality from surface runoff with water quality standards is analogous to the comparisons for effluent discharges. Techniques for predicting effluent quality are presented in *Environmental Effects of Dredging Technical Notes* EEDP-04-1 through EEDP-04-4 (Palermo 1985) and EEDP-06-13 (Palermo and Schroeder 1991). Guidance for performing a surface runoff quality test is provided by Lee and others (1991). After such tests are performed, each contaminant of concern is compared with applicable water quality standards. Prediction of surface runoff quality is covered in *Technical Note* EEDP-02-3 (Skogerboe and Lee 1987), which addresses analysis of surface runoff from confined upland disposal sites to develop appropriate management plans before dredging. This procedure was developed as part of the Field Verification Program.

After predicting surface runoff water quality, and comparing this with standards and computing the dilution requirements, as described in this technical note, the required size of a mixing zone is computed. Guidance for calculating the size of the mixing zones can be found in *Technical Note* EEDP-04-5 (MacIntyre 1987). The required dilution of each contaminant of concern to meet its respective water quality standard must be determined prior to calculating the size of the mixing zone.

Additional Information

This technical note was written by Dr. Paul R. Schroeder, Mr. Anthony C. Gibson, and Mr. Elba A. Dardeau, Jr. Questions regarding this technical note should be directed to Dr. Schroeder, (601) 634-3709; the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler, (601) 634-3624; or the manager of the Dredging Operations Technical Support Program, Mr. Thomas R. Patin, (601) 634-3444.

RUNQUAL Application of ADDAMS

Requirements

Surface runoff is the drainage of water by overland flow resulting from a precipitation event. The runoff often contains quantities of soil nutrients and contaminants scoured from the surface of the land. Predictions of soil loss and surface water quality are developed by simulating the runoff process in a laboratory test.

The surface runoff water quality test was developed under the Environmental Impact Research Program to predict soil loss and surface water quality at U.S. Army Corps of Engineers construction sites (Lee and Skogerboe 1984). The test was further refined and field verified for confined upland disposal of contaminated dredged material under the Field Verification Program (Skogerboe and others 1987). The test apparatuses consist of the U.S. Army Engineer Waterways Experiment Station's (WES) rotating rainfall disk simulator, which is

designed to duplicate the kinetic energy of natural rainfall (Westerdahl and Skogerboe 1982), and large laboratory lysimeters (25 by 5 by 2 ft) placed in a temperature-controlled greenhouse.

Sediment is collected from a proposed dredging site, brought to WES, and tested during both the wet anaerobic and dry oxidized stages. The wet anaerobic stage represents dredged material immediately following drainage of the ponded water from the confined disposal facility. Its oxidation state is the same as that of the original sediment. The dry oxidized state represents aged dredged material following crust formation of the surface material. Results are then statistically compared to water quality criteria chosen by the agency sponsoring the study (Skogerboe and Lee 1987). Predicted concentrations can be used with appropriate water quality standards to determine the size of the mixing zone required to dilute the runoff discharge to an acceptable level. Before mixing zone calculations are made, the required dilution of each contaminant of concern to meet water quality standards must be calculated.

Comparison of the predicted surface runoff concentration with the water quality standard and, if necessary, calculation of the dilution required to meet the water quality standards must be determined for each contaminant of concern. For some projects, the number of contaminants of concern can approach a hundred. The predicted surface runoff concentration during each of the two stages, the water quality standard, and the background concentration of the contaminant in the receiving water all influence the dilution required. Further complicating the process is the fact that any of these concentrations may exceed the others, and some of the concentrations may be below the detection limit of the chemical analysis used to predict the surface runoff concentration. Because the computational effort and data management effort required for such an evaluation can be substantial, a computer program has been developed to efficiently perform the required calculations, manage the data, and present the data and comparisons in a manner that can be easily interpreted.

RUNQUAL Capabilities

The RUNQUAL module, a computer program for surface runoff quality described in this note, has been developed as part of the Automated Dredging and Disposal Alternatives Management System (ADDAMS) and can be run on a personal computer. ADDAMS is an interactive computer-based design and analysis system in the field of dredged material management. The general goal of the ADDAMS is to provide state-of-the-art computer-based tools that will increase the accuracy, reliability, and cost-effectiveness of dredged material management activities in a timely manner. ADDAMS is described in more detail in *Technical Note* EEDP-06-12 (Schroeder and Palermo 1995).

RUNQUAL has the following capabilities:

- Computes predicted dissolved and total contaminant concentrations in the surface runoff discharged from a confined disposal site using surface runoff quality test data.
- Compares predicted surface runoff concentrations with specified water quality standards.
- Computes required dilutions of surface runoff discharge to meet specified water quality standards, considering background concentrations in the receiving water.

Availability

RUNQUAL, as well as other modules of ADDAMS, is available through the Information Technology Laboratory of the U.S. Army Engineer Waterways Experiment Station. See Appendix A for an order form.

Using the RUNQUAL Module

The RUNQUAL module employs a menu-driven environment with a full-screen data entry method. The initial menu contains options for entering/editing input data, selecting existing data files or performing file management operations, selecting/entering/editing water quality criteria or standards, performing calculations, printing output, and exiting the RUNQUAL module. In general, single keystrokes are required to select menu options displayed on the screen. Cursor keys are used to select between highlighted input fields much like a spreadsheet program. Results from computations are generally displayed in tabular format on the screen; these can then saved in ASCII files or sent to a printer, or both. General on-line assistance is available by pressing the F1 key. The F2 key offers detailed assistance on the highlighted input field.

Input/Output

The main data requirements for the RUNQUAL module include surface runoff quality test conditions for both the wet anaerobic and the dry oxidized material and results, background receiving water concentrations, and water quality standards for contaminants of concern. Other data describing the samples and parameters used in the surface runoff quality tests can also be entered for documentation purposes. The input data are stored in a file with a user-specified name and an extension of .RUI. The water quality standards are stored in a file called CRITFILE.DAT, the same file as used with the EFQUAL module.

The final output of the module consists of tabular summaries of surface runoff quality data, predicted surface runoff quality concentrations and water quality standards; absolute and statistical comparisons of predicted surface runoff water quality with standards; and computed dilutions required to meet the standards. The summary of input values and predicted concentrations are stored in a file with the user-specified name with an extension of .RUS, while the results of comparisons and dilution computations are stored with the same

user-specified name but with an extension of .RUC. Table 1 shows the necessary input parameters with their corresponding units. Instructions for data entry and additional descriptive information for some parameters are provided directly on the RUNQUAL input screens or are available from the on-line user guide.

Table 1 RUNQUAL Input Parameters	
Parameter	**Unit**
For each evaluation: Descriptive title Number of surface runoff replicates	N/A number
For each runoff replicate: Sediment age (optional) Rainfall duration (optional) Rainfall intensity (optional) Total suspended solids (TSS) concentration	years hr cm/hr mg/L
For each contaminant of concern: Detection limit Test sediment concentration (optional) Test water concentration (optional) Background water concentration Water quality standard	µg/L mg/kg µg/L µg/L µg/L

For each contaminant of concern and each surface runoff replicate:
Surface runoff dissolved concentration
Surface runoff total concentration
  (required only if total concentrations used
  for prediction of quality or comparison to standards)
	µg/L
	µg/L

For each evaluation:
Estimated surface runoff discharge TSS concentration
  (required if total concentrations used for
  prediction of quality or comparison to standards)
Percentage increment above background for dilution
  calculations (used when standards are below or
  very close to background concentration)
	mg/L
	
	percent

Considerations in Comparing Predictions with Criteria

Contaminants of Concern and Water Quality Standards

Prior to entering water quality standards or surface runoff test data, the user must build a list of all contaminants of concern. This list must contain the names of all contaminants measured in the surface runoff tests or listed in any water quality criteria set of interest, such as the Federal freshwater acute and marine toxicity water quality criteria sets, the Federal drinking water standards, or state water quality standards. The RUNQUAL module comes with a list of contaminants for the Federal freshwater and marine acute toxicity water quality criteria sets. To update the list, the user should select the water quality criteria set option of the RUNQUAL module and then choose the criteria set of interest or build a new criteria set (up to a maximum of 12 sets). The program will display the current list of contaminants and provide instructions for adding or deleting names from the list.

When building or editing the list of contaminants, the user should also enter the available water quality standard for all contaminants of interest. Entry of the standard is made on the same screen in a column adjacent to the entry of the contaminant name. Many of the contaminants initially listed on the screen may not have standards for the selected criteria set but may have values in other criteria sets. A standard entered as equal to or less than zero will be treated as a missing value. Contaminants having missing values in the selected set should not be deleted from the list because the contaminant may be used for other criteria sets.

RUNQUAL allows the user to compare contaminant values with several sets of criteria. The EPA acute water quality criteria for protection of freshwater or saltwater aquatic life are initially available as choices. Chronic criteria are technically inappropriate because water column effects are considered short term because of the intermittent, short-term nature of runoff. As noted earlier, RUNQUAL allows the user to build additional sets of water quality standards (for example, state standards specified under section 401 water quality certifications), which can then be permanently stored in the table of standards for use in future evaluations. The water quality standards may be left blank if a standard does not exist for a particular contaminant. If no water quality standard for a given contaminant is specified in the set of standards selected for comparison, RUNQUAL displays N/A (not applicable) blanks for the standard and comparison results.

Surface Runoff Test Description

Surface runoff test results and related information comprise the majority of the data set that must be entered. For each new data set, a text description of the samples used for the tests can be included for documentation purposes. The description should indicate the oxidation stage of the sediment because

one data set should be entered for the wet anaerobic stage and another for the dry oxidized stage.

The surface runoff procedure requires that the test be performed with a minimum of three replicates. Up to nine replicates can be entered in RUNQUAL. Separate sets of replicates of the surface runoff test may be analyzed for classes of contaminants (for example, metals or organics). Therefore, the definition of a replicate for purposes of RUNQUAL is any separate sample analyzed for chemical concentrations and for which a separate total suspended solids determination is made. The TSS concentrations can be used to differentiate between replicates during data entry. The sediment age, the rainfall duration, the rainfall intensity, and the TSS concentrations for each replicate are then specified. The sediment age is an indication of whether the samples are tested in the wet anaerobic stage or the dry oxidized stage.

Sample Contaminant Data

RUNQUAL displays a table of the contaminants of concern for purposes of entering the surface runoff and other data for specific contaminants. The test data can be entered for any contaminant listed on the displayed table of contaminants by a menu selection. RUNQUAL marks those contaminants with an asterisk on the displayed table for which data have been entered. All data previously entered for a contaminant can be deleted by highlighting the contaminant of interest and then depressing the DEL key.

Once a specific contaminant has been selected for data entry, RUNQUAL presents an input screen for that contaminant. Data from the surface runoff quality test procedure include dissolved concentrations of contaminants, total concentrations of contaminants, and the TSS concentration (see *Technical Note* EEDP-02-3, Skogerboe and Lee 1987). These data are used to compute the contaminant fraction of the TSS and to predict the total concentration of contaminants in the surface runoff for any TSS loading (Skogerboe and Lee 1987). The RUNQUAL module automatically performs the needed data reduction and displays the results.

The test sediment concentration and test water concentration for the contaminant may be entered for documentation purposes; however, these parameters are not used in any calculations. The detection limit, the background water concentration, and the dissolved and total surface runoff concentrations for the contaminant are required for the computations. RUNQUAL displays the TSS concentration for all replicates to aid in replicate identification for each contaminant of concern. Care should be exercised in entering the data to ensure accurate computation of total contaminant concentrations.

Once the dissolved and total concentrations for a replicate are entered, RUNQUAL calculates and displays a value for the contaminant fraction of the TSS. If the contaminant concentration for a replicate as determined by the test is below detection, a zero may be used for ease of data entry; however, the value of the detection limit with a less than sign (<) is displayed by the

program. If the entered value of the dissolved concentration for any replicate exceeds that for the total concentration (a possibility considering variability and low concentrations), a value of zero is displayed for that contaminant fraction. After any replicate data are entered or edited, the program calculates and displays values of the mean and standard deviation for the dissolved and contaminant fractions data. No statistics are displayed for the surface runoff total concentrations; their mean has little value because the suspended solids concentration may vary among the replicates.

Detection Limits

The detection limit entered for each contaminant of concern plays a potentially important role in later computation of dilutions. The value entered should be the detection limit for chemical analysis of the surface runoff samples. If the surface runoff concentration of all replicates analyzed is below detection, the mean is assumed to be zero, and zero is used in subsequent computations. If one or more of the replicates is above detection limit, the detection limit is assumed for any replicates with values below detection in computing the mean. This approach is conservative in that the predicted surface runoff discharge concentration will be higher than if zero were assumed for replicates below detection.

Background Concentrations

The value of background concentration for each contaminant is used for later computation of dilutions. This value must be determined by a separate chemical analysis of the receiving water. If the background water or test water concentrations are below detection, a value equal to the detection limit is used in the computations of required dilution. This assumption is conservative in that the required dilution will be greater than if zero were assumed for the background concentration.

Predicted Surface Runoff Concentrations

The RUNQUAL module computes both predicted dissolved and total surface runoff concentrations. The predicted dissolved concentrations are equal to the mean of the surface runoff dissolved concentrations. If the total surface runoff concentrations will be used in the evaluation, a value of the anticipated runoff TSS concentration must be given to compute the total concentrations. Results from the surface runoff test should be used to determine the surface runoff discharge TSS concentration (see Skogerboe and Lee 1987 and Lee and others 1991). The total contaminant concentrations are computed using the dissolved surface runoff test concentrations, the computed contaminant fractions in the TSS, and the specified surface runoff TSS concentration (Skogerboe and Lee 1987). Either the dissolved or total surface runoff discharge concentrations can be used for comparison with specified water quality standards and for computing required dilutions to meet standards, although typically only the dissolved contaminants readily contribute to toxicity and bioaccumulation.

Evaluation of Results

Comparison of Surface Runoff with Standards

The most useful output from the RUNQUAL module is the comparison of predicted surface runoff concentrations with specified water quality standards. The user has an option to choose either the dissolved or total surface runoff discharge concentrations and one of several sets of standards for the comparison. Any water quality standards imposed as part of a section 401 water quality certification should be based on potential for environmental impact. The standards are usually set in terms of dissolved concentrations, but could be set in terms of total concentrations. Care should be exercised in selecting the appropriate predicted surface runoff concentration (dissolved or total) for comparison to the standards. For example, if the standards are equivalent to or are based on the EPA acute water quality criteria, comparison of dissolved surface runoff concentrations is technically appropriate. The EPA criteria were developed using effects data for exposure of organisms to dissolved concentrations of contaminants.

Whenever a comparison of the predicted surface runoff concentration and a standard is possible and data for multiple replicates are available, a statistical comparison is also made between the mean of the replicate data and the standard considering the variance of the replicate data. The statistical test performed is a two-tailed Student's t-test (Miller and Freund 1985). The result of the test is the confidence level of the result (percent) that the predicted concentration exceeds the standard (i.e., $P > S$) or that the standard exceeds the predicted concentration (i.e., $S > P$). If the confidence is less than 50 percent, the test results indicate that the two values are essentially equal; more specifically, the confidence level of the two values not being equal is less than 50 percent (that is, $P \neq S < 50$ percent).

Calculation of Dilution Factor

If the predicted surface runoff concentration exceeds the standard and the standard exceeds the background concentration, a value for dilution to meet the standard is calculated. However, if both the surface runoff and background concentrations exceed the standard, neither the standard nor the background concentration can be met by dilution. For this case, the user specifies a percentage above the background concentration for which a dilution will be calculated (110 percent of the background or 10 percent above background is recommended for this value). Similarly, if the background concentration is less than but very close to the standard, very large dilution would be required for surface runoff to meet the standard. Consequently, dilution to the percentage above the background is also computed for this condition. If the background concentration is below detection, the detection limit is used for the background concentration. Use of the detection limit for background under this condition is conservative and will result in the largest dilution that could be required for the given standard and surface runoff discharge concentration.

The RUNQUAL module computes dilution factors for each contaminant of concern using the following equation whenever the surface runoff concentration is greater than the standard to be met:

$$D = \frac{P - S}{S - B}$$

(1)

where

D = dilution factor required to dilute the contaminant of concern to the appropriate water quality standard, in volume of background water/ volume of surface runoff

P = concentration of the contaminant of concern in the surface runoff, µg/L

S = receiving water quality standard for the contaminant of concern, µg/L (or a concentration equal to the specified percentage above background concentration)

B = background concentration of the contaminant of concern in the receiving water, µg/L

Three concentration variables are used in the above equation. When the detection limit and a specified percentage above background are considered, a total of five concentrations are possibly used in the comparison. A total of 60 different conditions are possible, considering every possible combination of the relative magnitude of the five concentrations. However, many of the conditions result in the same conclusion with respect to the interpretation of the comparison and dilution factor required, leaving only eight meaningful cases. These eight cases are illustrated in Figure 1. Additional discussion of each of the eight cases is given below. In addition to the abbreviations D, P, S, and B defined above, the following abbreviations are used in the descriptions of the cases:

xB = concentration equal to a multiple, x, of the background and replaces S in Equation 1 when $S \leq xB$

L = detection limit for tests and replaces B in Equation 1 when $L > B$

Case 1: $S > L > P$. The predicted concentration is less than the detection limit, and the detection limit is less than the standard. The standard is met with no dilution, and the RUNQUAL program displays the comment **D = 0** for the dilution required.

Case 2: $L > (S,P)$. The predicted concentration and standard are both less than the detection limit. The test results do not clearly indicate that the standard is met because the exact concentration of the surface runoff is unknown, and the RUNQUAL program displays the comment **D = 0, L > (S,P)** for the dilution required.

Case 3: $(S,B) > P > L$. All concentrations are greater than the detection limit, and the predicted concentration is less than the standard and the background. Under these conditions the surface runoff is cleaner than the background receiving water
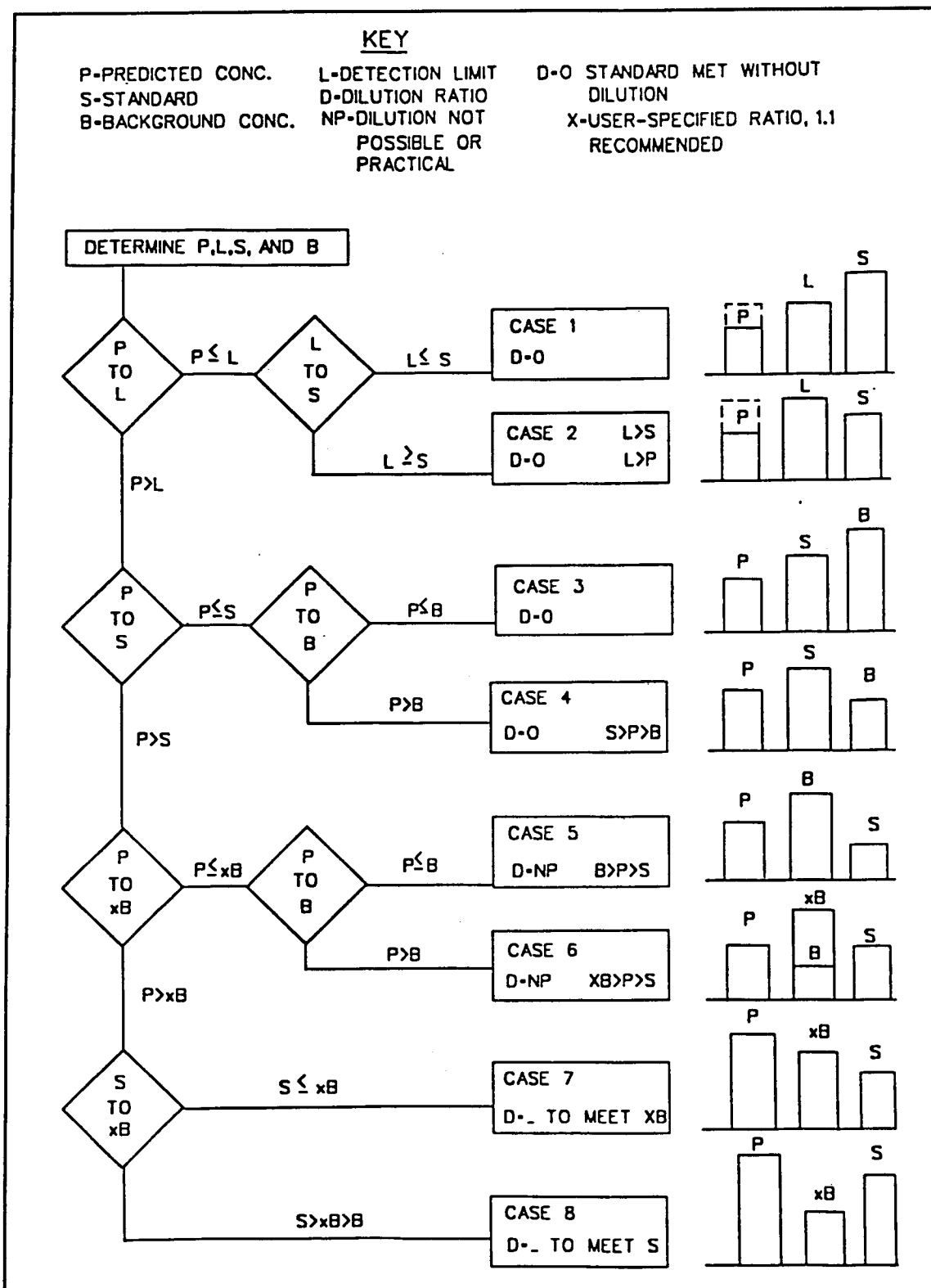
Figure 1. Possible conditions for comparison of runoff concentrations with sediments

for the contaminant of concern. The standard is met with no dilution, and the RUNQUAL program displays the comment **D = 0** for the dilution required.

Case 4: S > P > (B,L). The predicted concentration and standard are greater than the detection limit, and the predicted concentration is less than the standard; however, the predicted concentration is greater than the background. The standard is met with no dilution, and the RUNQUAL program displays the comment **D = 0 S > P > B** for the dilution required. An acceptable deterioration of the background receiving water occurred.

Case 5: B > P > (S,L). The predicted concentration and background are greater than the detection limit and the standard, but the predicted concentration is less than background. Under these conditions the standard is less than the background, and the receiving water is already in violation of the standard. Because the predicted concentration is less than the background, the receiving water will be improved for the contaminant of concern. No dilution is possible, and the RUNQUAL program displays the comment **D = NP B > P > S** for dilution required.

Case 6: xB > P > (B,S,L). The predicted concentration exceeds the detection limit, the standard, and the background; however, the predicted concentration is less than the specified percentage above background. Under these conditions, the predicted concentration is only slightly above the background; therefore, dilution is not practical. In addition, the receiving water is already or nearly in violation of the standard. Because the predicted concentration exceeds the background, some degradation of the receiving water will occur. No dilution is practical, and the RUNQUAL program displays the comment **D = NP xB > P > S,B** for dilution required. If $B < L$, L is used in place of B to compute xB.

Case 7: P > xB > (S,L). The predicted concentration exceeds the detection limit, the standard, and the specified percentage above background, and the specified percentage above background exceeds the standard. Under these conditions, the receiving water is already or nearly in violation of the standard. Since the predicted concentration also exceeds the background, degradation of the receiving water will occur. Dilution to meet the specified percentage above background is calculated because the background exceeds or is very close to the standard. The RUNQUAL program displays the comment **D = ##### to meet xB**, where ##### is the value of the required dilution computed by the program. If $B \leq L$, L is used in place of B to compute xB, xB is used as S, and L is used as B in Equation 1.

Case 8: P > S > (xB,L). The predicted concentration exceeds the detection limit, the standard, and the specified percentage above background, and the standard exceeds both the background and the specified percentage above background. The dilution to meet the specified standard is calculated, and RUNQUAL enters the comment **D = ##### to meet S**, where ##### is the value of the required dilution computed by the program. If $B < L$, L is used in place of B in Equation 1.

Summary

These procedures provide a consistent, rational, and conservative approach to compare predicted surface runoff water quality with water quality standards. In addition, the approach computes dilution requirements that are needed to evaluate mixing zones.

References

Lee, C. R., and Skogerboe, J. G. 1984. "Restoration of Problem Soil Materials at Corps of Engineers Construction Sites," Miscellaneous Paper EL-84-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Tatem H. E., Brandon, D. E., Kay, S. H., Peddicord, R. K., Palermo, M. R., and Francingues, N. R. 1991. "General Decisionmaking Framework for Management of Dredged Material; Example Application to Commencement Bay, Washington," Miscellaneous Paper D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

MacIntyre, D. F. 1987. "Interim Procedures for Estimating Mixing Zones for Effluent from Dredged Material Disposal Sites (Single-Point Discharge)," *Environmental Effects of Dredging Technical Notes* EEDP-04-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, I., and Freund, J. E. 1985. *Probability and Statistics for Engineers*, Prentice-Hall, Englewood Cliffs, NJ.

Palermo, M. R. 1985. "Interim Guidance for Predicting the Quality of Effluent Discharged from Confined Dredged Material Disposal Areas," *Environmental Effects of Dredging Technical Notes* EEDP-04-1 through -4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Palermo, M. R., and Schroeder, P. R. 1991. "Documentation of the EFQUAL Module for ADDAMS: Comparison of Predicted Effluent Water Quality with Standards," *Environmental Effects of Dredging Technical Notes* EEDP-06-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Schroeder, P. R., and Palermo, M. R. 1995. "The Automated Dredging and Disposal Alternatives Management System (ADDAMS)," *Environmental Effects of Dredging Technical Notes* EEDP-06-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Skogerboe, J. G., and Lee, C. R. 1987. "Upland Disposal Site Management for Surface Runoff Water Quality," *Environmental Effects of Dredging Technical Notes* EEDP-02-3, U.S Army Engineer Waterways Experiment Station, Vicksburg, MS.

Skogerboe, J. G., and others. 1987. "Prediction of Surface Runoff Water Quality from Black Rock Harbor Dredged Material Placed in an Upland Disposal Site," Miscellaneous Paper D-87-1, U.S Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Environmental Protection Agency (EPA). 1980. "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," *Federal Register*, Vol 45, No. 249, pp 85336-85358.

Westerdahl, H. E., and Skogerboe, J. G. 1982. "Realistic Rainfall and Watershed Response Simulations for Assessing Water Quality Impacts of Land Use Management; Modeling Components of Hydrologic Cycle," *International Symposium on Rainfall - Runoff Modeling*, Mississippi State University, Mississippi State, MS.

Appendix A: Request Form for ADDAMS

Please send the ADDAMS diskettes to:

Name and Title _____

Mailing Address _____

and Office Symbol_____

_____

Telephone Number_____

Anticipated Uses of ADDAMS _____

_____

Requests for ADDAMS must be sent with *formatted* floppy disks. Please circle the applications desired and the number and type of diskettes enclosed.

Requested Modules	Number of diskettes enclosed (all DS)			
	5.25 in. 360 kb	5.25 in. 1.2 Mb	3.5 in. 720 kb	3.5 in. 1.44 Mb
ADDAMS (all modules)	26	14	16	9
ADDAMS DEMO	6	3	3	2
SETTLE	2	1	1	1
DYECON	2	1	1	1
PCDDF	2	1	1	1
D2M2	1	1	1	1
STFATE	10	4	6	3
EFQUAL	1	1	1	1
RUNQUAL	1	1	1	1
EXECUTIVE SHELL	1	1	1	1

Signed_____Date_____

MAIL THE COMPLETED REQUEST FORM AND FORMATTED DISKETTES TO:

U.S. Army Engineer Waterways Experiment Station
ATTN: CEWES-IM-DS (Naylor)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199